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THE DECLINE OF NATIVE BROOK TROUT *(SALVELINUS FONTINALIS)* POPULATIONS ALONG THE UPPER WEST BRANCH OF THE SUSQUEHANNA RIVER: CANARIES OUTSIDE THE COAL MINE[1]

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ABSTRACT

Native brook trout (*Salvelinus fontinalis*) are widely distributed in suitable habitat in Pennsylvania. Over 200 km of streams in the upper West Branch of the Susquehanna River drainage system were surveyed periodically from 1981-1995 for the presence of brook trout. Brook trout were found in 68% of the stream distance surveyed, including 66% of the first order stream segments. Higher order streams were more likely to be occupied by brook trout and had proportionately more stream distance of brook trout habitat than lower order streams. Few other fish species were collected during the survey. The primary cause of brook trout extirpation in the area is acid mine drainage from surrounding bituminous coal mines which occupy significant portions of the regional landscape. Atmospheric deposition of strong acids in these poorly buffered streams has undoubtedly contributed to the extirpation of brook trout populations. In a subset of streams that did not contain brook trout, pH ranged from 3.8-4.7. Unpolluted headwater streams provide important refugia for native fish populations for recolonizing the polluted but recovering West Branch of the Susquehanna River and its major tributaries.

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INTRODUCTION

The brook trout (*Salvelinus fontinalis*) is the only native stream salmonid in Pennsylvania (Cooper, 1983). Although the species is a popular game fish and has been stocked worldwide (McAfee, 1966), native brook trout populations have experienced significant declines in portions of the eastern United States as a result of habitat destruction (Lovich, 1984) and possible negative interactions with non-native species such as rainbow trout (*Onchorynchus mykiss*; Schmitt et al., 1993). Recent research suggests that their sensitivity to small changes in habitat quality makes them potentially susceptible to global and regional changes including acid deposition from precipitation (Sharpe et al., 1984, 1987; Webb et al., 1989) and global warming (Meisner, 1990). In recognition of the declining stocks of this species, their importance as an ecological indicator species (Jenkins, 1979; Camuto, 1988) and their intrinsic value (Knuth, 1994), some states have instituted surveys to determine their surviving range (Mohn and Bugas, 1980; Bugas and Mohn, 1981; Pennsylvania Fish and Boat Commission, pers. comm.).

While Pennsylvania still supports widespread and healthy native brook trout populations (Pennsylvania Fish and Boat Commission, pers. comm.) some parts of the state have experienced significant declines of the fishery due to habitat degradation and destruction. In particular, acid mine drainage has had devastating effects on fish populations in the West Branch of the Susquehanna River and its associated tributaries (Cooper and Wagner, 1973; Hocutt and Drawas, 1975). The objective of our paper is to present the results of an inventory of native trout populations in a portion of the upper West Branch of the Susquehanna River watershed.

MATERIALS AND METHODS

Streams were periodically surveyed for the presence or absence of brook trout in portions of northeastern Indiana County, southwestern Clearfield County and extreme southeastern Jefferson County, Pennsylvania (Figure 1) between 1981 and 1995. Data reported in this paper are based on observations taken from streams draining into the upper West Branch of the Susquehanna River (WBSR) from its confluence with Shryock Run downstream to the mouth of Whisky Run. Beaver Run, a large state stocked stream with a self-sustaining population of brook trout, was excluded unless noted otherwise. Cush Creek and Sawmill Run are the only other state stocked streams in the study area. We also included streams draining into Cush Creek, a major tributary of the WBSR, downstream from the mouth of the West Branch of Cush Creek (this stream is near the towns of Gipsy and Hooverhurst, outside the boundaries of Figure 1) to its confluence with the WBSR. The upper portion of

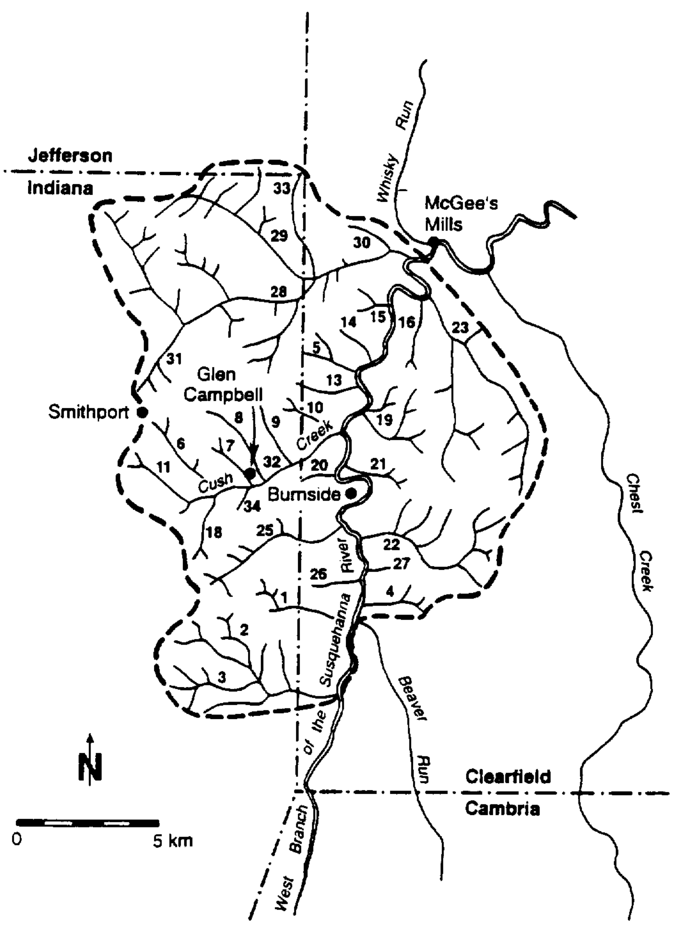

FIGURE 1. Map of the study area surveyed for the presence of native brook trout. Stream numbers follow Table 1. Map modified from Higbee (1965).

Cush Creek excluded in this survey has a drainage area of approximately 29 km^2. The study area contained a total of 208.75 km of streams with a drainage area of approximately 180 km^2. The drainage area of named tributaries of the WBSR in the study area ranges from 2.31-55.44 km^2 with a mean of 16.66 km^2 (U.S. Geological Survey, 1989).

Stream lengths were determined by averaging the results of three passes with a map wheel on U.S. Geological Survey 7.5 minute quad sheets showing permanent and intermittent streams. Stream names follow those shown on the quad sheets. All streams, including unnamed streams, are numbered and referenced in Table 1 and Figure 1. Stream order designation follows Strahler (1957).

TABLE 1. List of stream units surveyed for the presence of native brook trout. Local names of streams are noted with footnotes. Stream numbering is for convenience and matches that of Figure 1. Stream lengths (km) include all tributaries shown on 7.5 minute maps. Latitude and longitude, demarcating the mouth of the stream, are given in degrees-minutes-seconds. Not all streams are independent: some are tributaries of other stream units named in the table. Streams that contained brook trout during the course of the study are marked with an asterisk. Stream numbers 12, 17 and 24 were not included in this study.

Stream	Stream #	Order	Length	Latitude	Longitude
Boiling Spring Run*	1	2	5.18	40-46-28	78-47-05
Shryock Run*	2	3	12.79	40-45-12	78-47-22
Powell Run*	3	2	8.80	40-45-20	78-48-31
Patchin Run*	4	2	3.35	40-46-55	78-46-48
Martin Run*	5	2	4.88	40-50-57	78-47-09
Horton Run	6	1	3.70	40-48-48	78-50-09
Unnamed[1]*	7	1	2.14	40-48-48	78-48-28
Unnamed[2]	8	2	6.41	40-49-01	78-49-06
Unnamed[3]	9	2	3.96	40-49-11	78-48-31
Unnamed[4]*	10	1	2.64	40-49-43	78-47-37
Unnamed[5]*	11	1	2.74	40-48-34	78-50-51
Unnamed[6]	13	1	2.12	40-50-41	78-47-07
Unnamed[7]*	14	1	2.14	40-51-05	78-46-47
Unnamed[8]*	15	2	3.35	40-52-04	78-46-19
North Run*	16	2	2.74	40-52-07	78-45-30
Unnamed	18	2	2.74	40-48-35	78-50-26
Unnamed[9]*	19	2	6.55	40-50-20	78-46-42
Unnamed	20	2	2.43	40-49-09	78-47-29
Unnamed[10]*	21	2	3.04	40-49-22	78-47-19
Sawmill Run*	22	2	14.53	40-47-54	78-46-59
Deer Run*	23	3	20.12	40-52-13	78-45-19
Rock Run*	25	3	11.89	40-48-10	78-47-12
Unnamed*	26	1	1.22	40-47-14	78-47-06
Unnamed	27	1	0.61	40-47-27	78-46-40
S. Branch Bear Run[11]	28	4	38.45	40-52-50	78-45-48
Bear Run[12]	29	3	18.28	40-52-35	78-48-32
Unnamed*	30	2	4.57	40-53-02	78-46-22
Unnamed[13]	31	2	3.96	40-51-47	78-50-56
Cush Creek*	32	3	6.71[14]	40-49-51	78-47-22
Unnamed[15]*	33	2	5.18	40-52-38	78-48-16
Unnamed	34	1	1.53	40-48-49	78-49-32

1. Glen Campbell Run
2. Brady Run
3. Urey Run
4. "Eugus Run"
5. Logan Run
6. Sportsman's Run
7. North School Run
8. Sam McGee Run
9. Elk Lick Run
10. Cherry Run
11. Bear Run
12. Hillman Creek
13. Mud Bridge Run
14. Only part of the stream was surveyed. Refer to text for details.
15. Murry Run

Fish were collected with a Coffelt backpack electroshocker using direct current following the techniques of Lovich (1992), under permits from the Pennsylvania Fish Commission. A small number of voucher specimens are housed at the University of Georgia Museum of Natural History (Appendix). Other streams were surveyed by licensed angling and occasionally by visual observation. Our estimates of stream distances occupied by brook trout are liberal in that we include entire segments of streams known to have brook trout unless we determined that some portions or tributaries did not have brook trout. Although brook trout were rarely found at the source of streams in the study area, many were occupied far into their headwaters making this a reasonable assumption (Cooper, 1983).

Limited data were collected on the pH of selected streams in the study area from 1979-1980.

RESULTS

Brook trout were found in 142 km (68%) of the stream sections surveyed. Relative to lower order streams, higher order streams contained greater proportions of occupied brook trout habitat as measured by linear distance (Table 2). Higher order streams were also more likely to have brook trout present than were lower order streams. Sixty-six percent of all first order stream segments surveyed contained brook trout compared with 83% of all third order streams (Table 3). However, data were too sparse, particularly for fourth order streams, to test the association between stream order and brook trout presence/absence using contingency table analysis without violating statistical assumptions. Using data summarized by U.S. Geological Survey (1989) in conjunction with our survey data, an estimated 159 km^2 (88%) of the drainage area of our study area is occupied by brook trout (including Beaver Run). Streams as small as 1.22 km contained thriving populations of brook trout.

Other fish species collected during the course of the survey included; *Rhinichthys atratulus*, *Salmo trutta*, *Semotilus atromaculatus*, and *Semotilus corporalis*. All species have previously been recorded from the Susquehanna River drainage system (Stauffer et al., 1982).

One stream with brook trout (Bear Run, Table 1) had pH values ranging from 5.0-5.6. Three streams without brook trout (all part of the South Branch of Bear Run, Table 1) had pH values ranging from 3.8-4.7.

DISCUSSION

Brook trout populations in the Allegheny Plateau region of Pennsylvania have been subjected to severe anthropogenic modification of the landscape and associated changes in habitat quality for centuries. Although brook trout populations are resilient in the face of natural cataclysms such as extreme natural flooding (Hoopes, 1975), they do not fare well in the face of wholesale conversion of landscapes and associated watersheds.

The first major regional impacts occurred during the extensive logging operations of the late 19th and early 20th centuries (Whitney, 1990). Clearcutting caused increased stream temperatures, increased siltation, unnaturally high floods (Tonkin, 1958), and other conditions that are detrimental to the health of brook trout populations (McAfee, 1966; Mohn, 1995). Later, extensive extraction of bituminous coal developed in the region with surface mining surpassing deep mining in production by 1977 (Phelps, 1983). Approximately 9.8% of the bituminous region of Clearfield County has been strip mined, followed by 2.5% and less than 1% of Indiana and Jefferson Counties, respectively (Schnell and Monmonier, 1983).

One of the negative outcomes of many past and present coal mining operations in Pennsylvania is the production of acid mine drainage and its attendant deleterious effects on stream organisms. Brook trout tolerate pH values from 4.1-9.5 (McAfee, 1966) but do very poorly in streams with a pH of less than 5.0 due to associated decreases in blood pH and the ability of blood to transport oxygen (Packer and Dunson, 1970). Their sensitivity to acid toxicity is heritable (Falk and Dunson, 1977) and generally decreases with age: survival of hatching, freshly fertilized and eyed eggs decreases dramatically at pH values of 5.2 or less, and survival of swim-up fry or yolk-sac fry decreases at pH values between 4.0-4.4 (Ingersoll et al., 1990). In addition, precipitation of $Fe(OH)_3$ in acid mine drainage causes decreased oxygen during formation and covers the gills, body surfaces and eggs of

TABLE 2. Summary statistics for stream lengths sampled during brook trout survey. Figures are in kilometers and percentages of row totals are in parentheses.

	Trout	
Stream order	Present	Absent
First	80.13 (66%)	40.44 (33%)
Second	41.39 (73%)	15.53 (27%)
Third	21.32 (80%)	5.17 (20%)
Fourth	0	4.81 (100%)
Total	142.85 (68%)	65.9 (32%)

TABLE 3. Frequency of brook trout presence/absence according to stream order. Row percentages are in parentheses.

	Trout	
Stream order	Present	Absent
First	20 (66%)	10 (33%)
Second	15 (68%)	7 (32%)
Third	5 (83%)	1 (17%)
Fourth	0	1 (100%)

fish living in the stream (Kimmel, 1983). During our survey brook trout were absent from all streams containing obvious $FE(OH)_3$ precipitate except for stream #11 (Table 1).

Pennsylvania has 4,800 km of streams polluted by daily mine drainage (Kimmel, 1983) including more than 780 km of streams in the WBSR basin (Kinney, 1964). Unfortunately, streams in the WBSR do not flow over extensive deposits of carbonate-bearing rocks and thus have little buffering capacity (Kimmel, 1983). As a result of the extreme degradation of many of the streams in the WBSR basin due to acid mine drainage, fish and invertebrate populations are depauperate or absent (Cooper and Wagner, 1973; Hocutt and Drawas, 1975) and this was confirmed during our survey. The surveys of Cooper and Wagner (1973) found many streams in the WBSR with no fish and pH values less than 4.5. In addition, they reported that brook trout were never observed in streams with pH values less than 5.0.

Even streams that are far removed from direct human activities are affected by atmospheric deposition of acids. Sharpe et al. (1987) surveyed 61 headwater streams on Pennsylvania's Laurel Hill and found that 12 (20%) did not contain trout and only 33 (54%) contained viable trout populations. Fish were absent in 10 (16%) of the streams surveyed. Streams without fish had lower pH and alkalinity, and higher dissolved aluminum relative to streams with fish. Watersheds buffered by limestone derived soils always contained trout. Data on acid runoff indicated severe episodic acidification following snowmelt and rain (Sharpe et al., 1984). Acid precipitation affects an estimated 3,236 km of stocked trout streams in Pennsylvania (Carline et al., 1992).

The principal factors governing the sensitivity of a stream ecosystem to acidification are the size of the drainage area and its buffering capacity. Since the dilution capacity of a stream system is largely dependent on quantity of flow, larger watersheds are less susceptible to acidification than small watersheds (Kimmel, 1983). Also, Carline et al. (1992) noted that because of atmospheric deposition of acids, Pennsylvania trout streams had lower pH values in their upstream reaches than they did downstream. These observations are consistent with our finding that higher order streams in the study area were more likely to have brook trout populations and more occupied habitat than lower order streams.

Judging from the low diversity of native fish species we encountered during our survey it appears that acid mine drainage and acid precipitation have had a profound effect on many of the species in the area. In most of the streams we surveyed, brook trout appeared to be the only fish present. Extensive surveys of Pennsylvania fish by Cooper and Wagner (1973) showed that brook trout were found at lower pH values than any of the other species we observed during our survey, suggesting that they persist when other species cannot. Alternative or synergistic explanations for low fish diversity include the infertile nature of many Pennsylvania trout streams (Cooper and Scherer, 1967; Hoopes, 1975) and the strong role brook trout play as piscivores (McAfee, 1966).

In other streams brook trout were absent in spite of stream conditions that looked superficially suitable for their survival (clean water, no obvious mine drainage, and forested watershed). Populations may have been extirpated from these streams due to atmospheric deposition of acids, stochastic events or acid mine drainage from old coal extraction activities. Some of these streams are isolated from other brook trout populations due to the fact that they drain into larger streams that are heavily polluted and do not support fish. When recolonization potential is zero, suitable streams should be evaluated for restocking with native brook trout and other native species from adjacent drainages.

The Pennsylvania Fish and Boat Commission, Division of Fisheries and Management completed a statewide inventory of trout populations. Surveys in Cush Creek during 1986-87 found significant improvements in water quality during the preceding 10 years despite extensive coal mining operations in the drainage system (Hollender and Wilberding, 1987). Brook trout biomass in the upper portion of the stream was estimated at 36.8 kg/ha including stocked fish. Based on the results of their survey they recommended reclassification of the upper stream from a cold water fishery to a high quality cold water fishery.

Similar surveys were conducted by the state in the South Branch of Bear Run and Bear Run in 1979 (Pennsylvania Fish and Boat Commission, file reports) and their results are largely congruent with ours. Not surprisingly, no trout were found in the lower South Branch of Bear Run due to intense acid mine drainage. As in our survey, no trout were collected in the upper tributaries of the South Branch of Bear Run but several *Semotilus atromaculatus* and nine families of invertebrates were present suggesting that some tributaries are suitable for restocking with brook trout. The Pennsylvania Fish and Boat Commission recommended Bear Run for continued management as a wild trout fishery. Our data suggest that this is one of the largest most pristine native trout fisheries in the study area and we recommend that the watershed be stringently protected.

Although Pennsylvania has thriving brook trout populations in many stream systems, some regions, such as our study area, have been severely depleted of their native trout stocks. However, small tributaries remain throughout the drainage that collectively support diverse populations of fish species, including brook trout, that are sensitive to high acidity (Cooper and Wagner, 1973). Thus, these streams are vital sources for natural restocking of native fish in the severely degraded but recovering upper West Branch of the Susquehanna River and its major tributaries (Cooper and Wagner, 1973; Hocutt and Drawas, 1975; Pennsylvania Fish and Boat Commission, file reports).

APPENDIX. List of fish collected and preserved during brook trout surveys along the upper West Branch of the Susquehanna River. Specimens are housed at the University of Georgia Museum of Natural History. Catalog numbers marked as "in part" are lot cataloged with other species from the same locality. Catalog numbers followed by numerals in parentheses indicate the number of specimens of the same species in the lot. Stream names follow those in Table 1.

Species	Catalog #	County	Stream	Collection Date
Rhinichthys atratulus	2843 (in part)	Indiana	Stream #33	26 Nov. 1981
Salmo trutta	2844 (in part)	Indiana	Stream #31	27 Nov. 1981
Salvelinus	2829-2830	Clearfield	Rock Run	2 Aug. 1981
fontinalis	2831 (2)	Clearfield	Sawmill Run	2 Aug. 1981
	2832	Clearfield	Stream #19	8 Aug. 1981
	2833 (3)	Clearfield	Martin Run	24 Jun. 1981
	2835 (2)	Clearfield	Stream #21	5 Sep. 1981
	2836 (in part)	Indiana	Stream #10	5 Sep. 1981
	2837 (3)	Clearfield	Stream #14	6 Sep. 1981
	2838 (3)	Clearfield	Stream #15	6 Sep. 1981
	2841 (3)	Indiana	Bear Run	26 Nov. 1981
	2843 (3, in part)	Indiana	Stream #33	26 Nov. 1981
Semotilus	2836 (in part)	Indiana	Stream #10	5 Sep. 1981
atromaculatus	2844 (in part)	Indiana	Stream #31	27 Nov. 1981

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